Design and fabrication of work holding device for a drilling machine

In partial fulfillment of the requirement for the degree of
BACHLEOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING
BY

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UNDER THE GUIDANCE OF
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CERTIFICATE

This is to certify that the Project report entitled **"Design and Fabrication of Work Holding Device for a Drilling Machine"**, submitted to the National Institute of Technology, Rourkela by **Mr. Pritam Kumar Kundu, Roll No**: **110ME0202** for the award of **Bachelor of Technology** in **Mechanical Engineering** is a bona-fide record of research work carried out by him under my supervision and guidance.

The candidate has fulfilled all the prescribed requirements.

The project report which is based on candidate's own work has not been submitted elsewhere for a degree/diploma.

In my opinion, the project report is of standard required for the award of a Bachelor of Technology in Mechanical Engineering.

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Abstract

The target of the mass production is to increase the productivity and increase the accuracy. This is done by reducing the set up cost and manual fatigue. Thus mass production can be achieved by the use of jigs. For large scale production of different materials a lot of time is wasted in set up of the device and clamping the device. Trial and error method is usually practiced until the axis of the hole is properly aligned with the axis of the drill. In such a situation a lot of time is being wasted to maintain the accuracy. Eventually it increases the operator's fatigue. Thus drill jig increases productivity by eliminating individual positioning, marking and frequent checking. The main advantage of the jigs is interchangeability. The need of selective assembly is eliminated. The parts of the jig will fit properly and in the assembly and all similar components are interchangeable. Also a jig reduces the repetitive nature required for drilling holes, because the locating, clamping and guiding of the tool is done by the jig itself. The tool guiding element is used whose chief work is to guide the tool in to the correct position. Hence the requirement of skilled laborers is eliminated. A fixture is a production tool. The main aim is to locate, hold and support the work securely so that the required machining operations can be performed. Set blocks and feeler or thickness gauges are also used to provide reference of the cutter with the workpiece. A fixture must be easily fastened with the table and the machine. As a result the work can be done. Fixture is largely used in milling machines. But it can also be used for other operations on most of the standard machining tools like drilling machine. Fixtures are available in different shape and sizes ranging from simple and cheap devices to very expensive and complicated devices. Fixtures can also help to simplify the metalworking operations which are performed on the special equipment. Considering the advantages of jigs and fixtures, a fixture was designed to cater to our needs.

1. Introduction:

Increasing the productivity and accuracy are the two basic aims of mass production. As we know the solution to this is by reducing the set up cost of the machine and also reducing the manual fatigue. In this case the device that caters our needs is the use of jigs. Let us take one example. Let us consider that one gets an order of say 1000 products. There need to be three holes drilled on this product. In such a case the designer tries to draw out every single hole with the help of square, straighteners, scribers and center hole. In order to align the axis of the hole with the axis of the drill we generally go for trial and error method. Accuracy is the main problem in such cases. In doing so it increases the work load on the operator. Hence using of jig to position and guide the tool to its right path is preferred rather than using scribers, square, straighteners or center punch etc. Thus the productivity is increased which is done by eliminating individual positioning, marking and frequent checking. Interchangeability is the chief advantage here. All the parts fit in properly except only the similar components are interchangeable. One does not need to repeatedly clamp and unclamp the object for various purposes like positioning as the locating, clamping and guiding of the tool is done by the jig itself. Bushing which is a tool guiding tool is used. So it reduces the presence of skilled laborer. Drill jig helps to drill, ream and tap at a much faster speed and with great accuracy as compared to holes done conventionally by hand. The responsibility of maintain the accuracy of the hole is now shifted from the operator and given to the jig.

May it be a drill jig or a drill fixture the necessity of a clamping device is inevitable. In case of a drill jig bushings are used. These drill bushings guide the drill bit during the drilling operation. Generally workpiece is held by a fixture and the fixture is arranged in such a way that the loading and unloading of the job is quick.

As we all know a fixture is a production tool which is mainly used to locate, hold and support the workpiece firmly to the table. Set blocks and feeler are sometimes used to provide reference of the cutter to the wrokpiece. The main concern is the fastening of the fixture. The fixture should be so chosen that the fastening of the job to the table is done quickly. It is mainly used in milling operation. But nevertheless it can also be used extensively in drilling machine

also for holding the job during the drilling operation. The size of the fixture varies from being simple to expensive and complicated. These fixtures also help in simplifying the network operations which are performed on special equipment.

The main difference between the jig and fixture is given in Table 1.

Table 1 Comparison between jigs and fixtures

Basis	Jig	Fixture
Definition	It is a work holding device that holds, supports and locates the workpiece and guides the tool for a very specific operation.	It is also a device that holds supports and locates the workpiece. But it differs from jig in way that it does not guide the tool for the operation.
Clamping	Jigs are not clamped to the drill table unless and until large diameter holes are to be drilled. Also there is necessity to move the jig to bring one bush directly under the drill.	Whereas fixtures should be securely clamped to the table of the machine upon which the work needs to be done. Also there is no requirement of alignment as bush is absent in fixture.
Operation	Jigs are special tools in operation particularly in reaming, tapping and boring.	Fixtures are specific tools used in milling, shapers and slotting machine.
Gauge block	Gauge blocks are not necessary.	Gauge blocks are necessary for effective handling.
Weight	Jigs are generally lighter in construction.	Fixtures are usually heavier in construction.

2. Design considerations:

The points that are taken into consideration for designing a product are as following:

a) Jig must be so strong that the deflection in the jig should be as less as possible. The deflection that is mentioned includes the forces of cutting, clamping of workpiece to the machine table. The frame of the fixture should have sufficient mass to prevent vibrations during the machining of the job.

b) Another important design consideration is the clamping which should be fast enough and require less amount of effort.

c) Arrangement of clamps should be such that they are easily available. They should also have the arrangement for easy removal as well.

d) Is swinging of clamp system is provided for removal of workpiece the clamp should swing as far as possible for unclamping the device.

e) There should also be provision for easy removal of chip. This will prevent the interference of the chip with the operation on the workpiece i.e. cutting operation.

f) The clamps and support points which are to be adjusted in due course of time should be preferred of same size. It will be better if the clamps and adjustable support points can be operated from the front of the fixture.

g) If the surface area of clamping is more it damages the workpiece. This can be avoided by making the surface area of clamping as small as possible.

h) As it is difficult to get spare parts during the operation so it is designed in such a way that they can be easily replaced on failure.

i) The study of the design should be done thoroughly before fabricating. It should always be ensured that the work is done in proper sequence. This will ensure zero loss of material. It

should always be preferred that there is maximum operation in a single setting of the workpiece.

j) The movement of the workpiece is restricted i.e. there is zero degree of freedom of the workpiece after clamping the workpiece. Sharp corners and redundant locators must be avoided. One should try to maintain at least one datum surface.

k) The design must possess enough rigidity and robustness to prevent vibration else it may lead to undesired movement of the workpiece and tools.

l) Minimum cost should be incurred during the fabrication of the project and the design should be as simple as possible. In such a way it will help even a lay man to operate the device.

m) Materials generally used are formulated in Table 2.

Table 2 Material requirement of different parts

Sl. No	Part name	Material
1	Jig body	Cast iron
2	Stud	Mild steel
3	Drill bush	Mild steel
4	Pin	Mild steel
5	Nut	Mild steel

3. Types of jigs:

3.1. Plate jig:

Plate jigs are in many ways similar to template jig whose diagram is shown in Fig.1. The only difference is that there is a location for built in clamps for holding the work in case of template jig. Bushings may or may not be provided in template jig. The factor on which the availability of the bushing depends is the number of jobs to be manufactured. Plate jigs can also made with legs which help in raising the jig off the table for machining of large work. This style is called table jig.

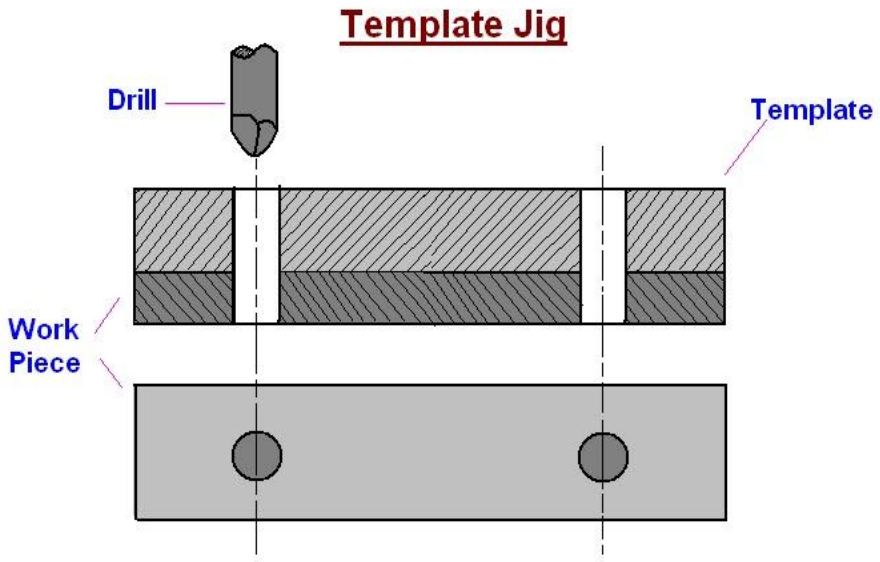

Fig.1 Template jig [1]

3.2. Leaf jig:

The diagram of leaf jig is shown in Fig.2. It is also called as open type jig. Here the top plate which is used to hold the job in its place is arranged in such a way that it swings about the fulcrum point as shown in Fig.2. Thus it helps in clearing the path completely for loading and unloading of the job to the device. The plate which covers the jig is called leaf, latch or lid. It

also has drill bushes fitted into it which guides the tool to its right position while machining the job.

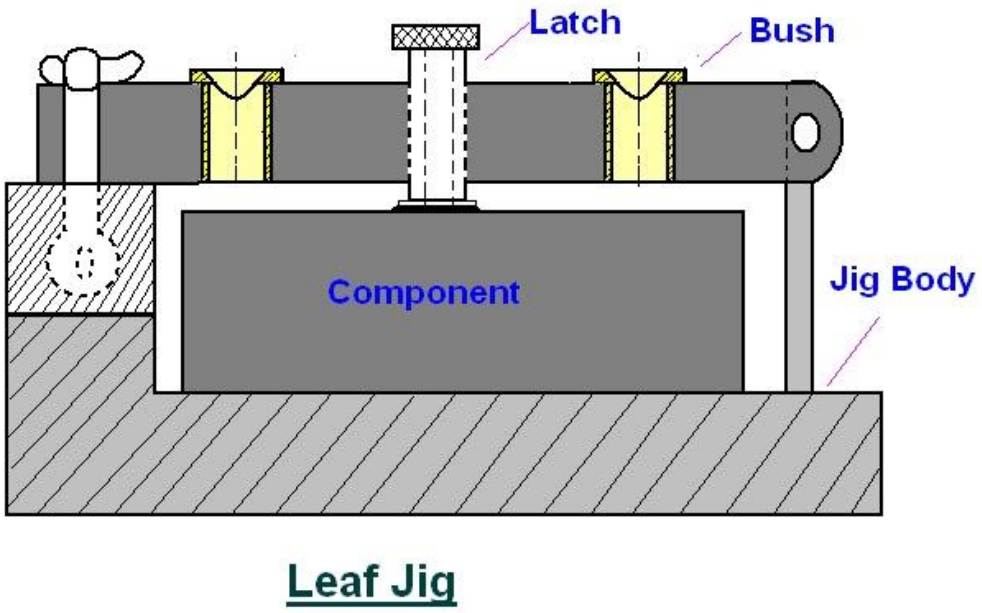

Fig.2 Leaf jig [1]

3.3. Box jig:

These are otherwise called as channel jig. It is used where there is drilling at number of distinct angles. Hence the part is to be held precisely while positioning the jig. The schematic diagram is shown in Figs.3 - 4. Here there are multiple locators placed on different walls of the box whose sole reason is to locate the workpiece securely while drilling is being carried out. Unlike leaf jig the box is being closed by the pivot wall. One should always try to avoid placing bushings on the moving walls of the jig. This helps in better accuracy.

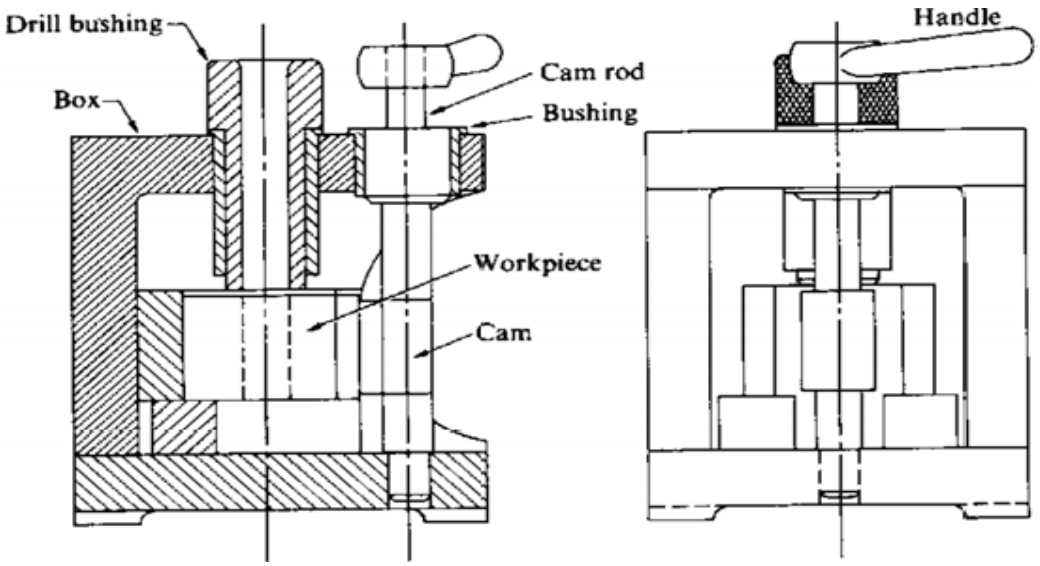

Fig.3 Box jig [2]

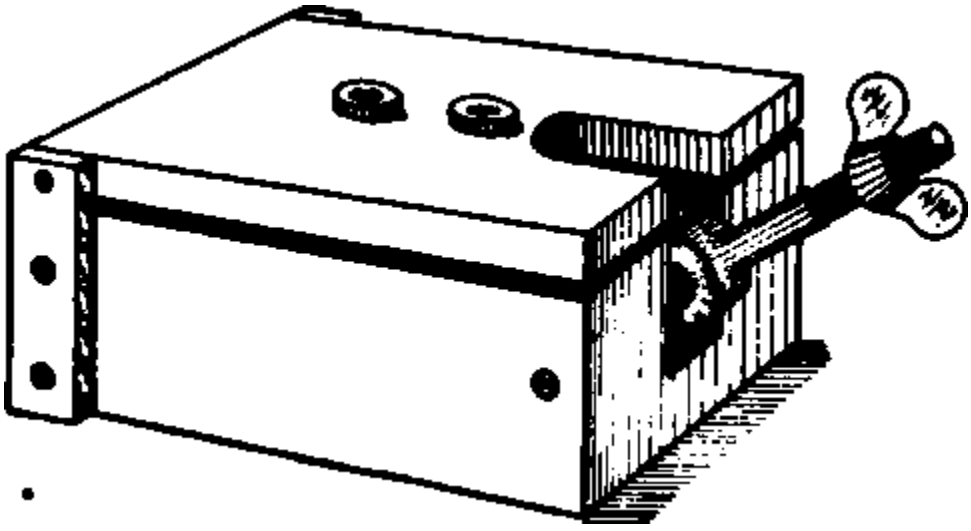

Fig.4 3D view of the box jig [3]

4. Clamping:

There are different types of clamps which help in clamping of the jib at the required position. Clamps hold the workpiece firmly. This helps in better engagement of job during the operation. Various forces develop during the cutting operation. The clamping should be such that it will sustain these forces during the operation. At the same time if clamping is so tight that it damages the workpiece then it must be avoided. The timing required for clamping and unclamping of the device should be as less as possible. These clamping must also restrict vibrations and chatter during the cutting operation.

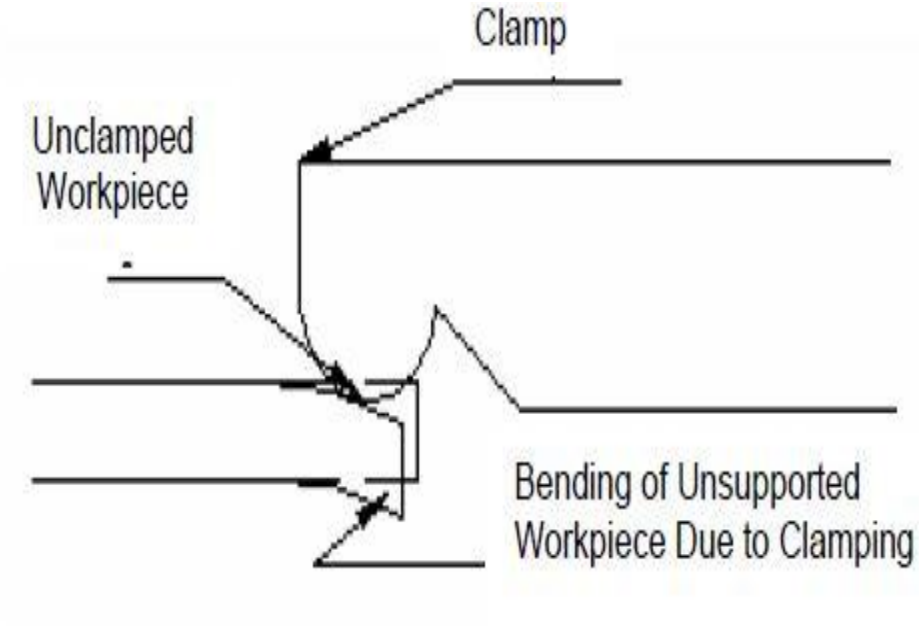

Fig.5 Distortion of unsupported part

4.1. Principles of clamping:

Various principles are followed during the clamping operation. Some of them are listed below.

a) The positioning of clamps should be done in such a way that clamping force does not act on weak and unsupported part of the workpiece. If clamping force acts on weak part of the jib it bends the job as shown in Fig.5. This will affect the accuracy of the drilling operation. Finally a straight drilled hole will become angular when the unclamped device comes back to its original position as shown in Fig.5 by dotted line.

b) The workpiece should be hold securely against the forces developed during the operation. It should also be taken care that the pressure of the clamping system does not affect the workpiece. For clamping of weak job instead of keeping the surface area less the surface area can be increased. It will prevent the damage of the workpiece. The clamps of the workpiece can be fitted with pads eg. Nylon or fiber. This prevents the damage to the job.

c) It should also be noted that the clamping of the job is not preventing the path of loading and unloading.

d) Time require for clamping should be as minimum as possible. This can be done using handles, hand wheels, hand knobs, tommy bars and knurled screws.

e) The points of clamping should be provided with sufficient radius. This radius will take care of the vibration of the job during the drilling operation. Sphere heel pin might be used to help in tilting the clamp. It is illustrated in Fig. 6.

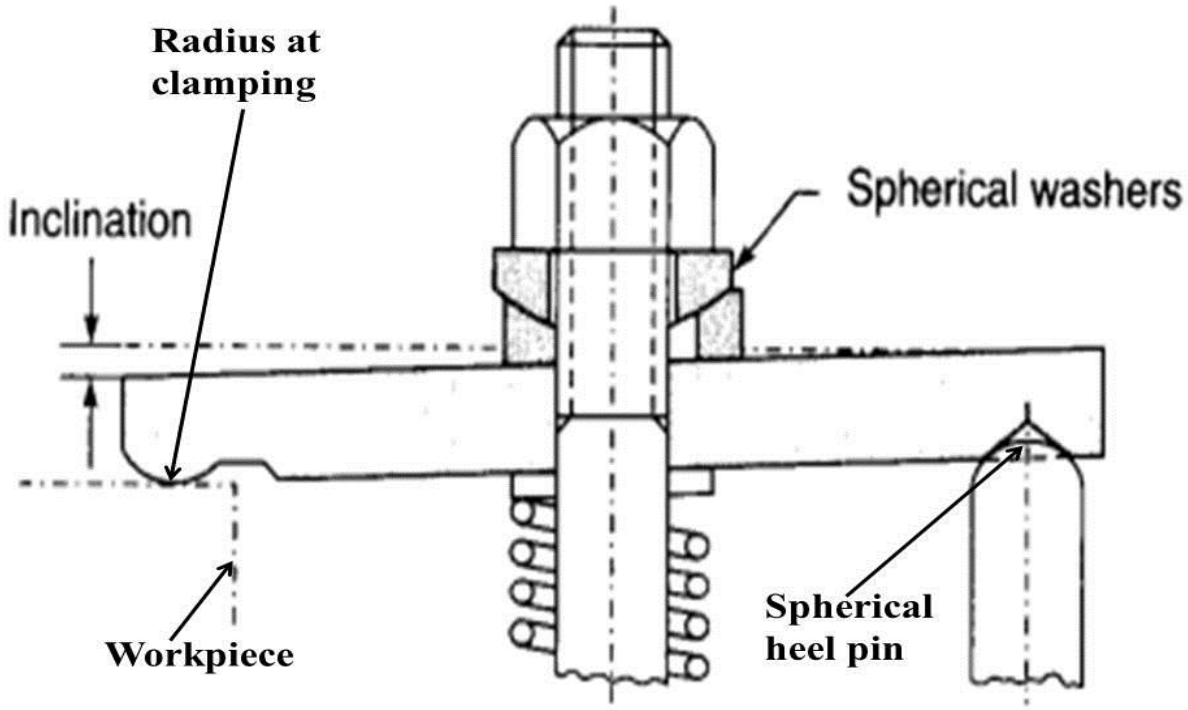

Fig.6 Clamping of workpiece [5]

4.2. Types of clamps:

4.2.1. Strap clamp:

Strap clamp is rectangular in shape and is easy to operate. It also acts as a lever. Hence it is used almost everywhere. It is shown in Fig.7. As the figure suggests the clamp is tightened by rotating the hexagonal nut on a central screw. The clamp has one end which presses against the workpiece and the other end presses against the heel pin. Thus the clamp acts like a simply supported beam. The clamping face of the workpiece is curved. It is done to prevent the extra pressure on the workpiece during the clamping. The press face of the clamp is curved. This is to take care of the variations of the surface of the job. There is also a spherical washer between the hexagonal nut and the clamp provides a spherical joint which allows clamp to tilt with respect to screw and nut. In this way the clamp takes care of the variations of the surface of the job. Usually washer and spring are provided below the claps of the strap clamp.

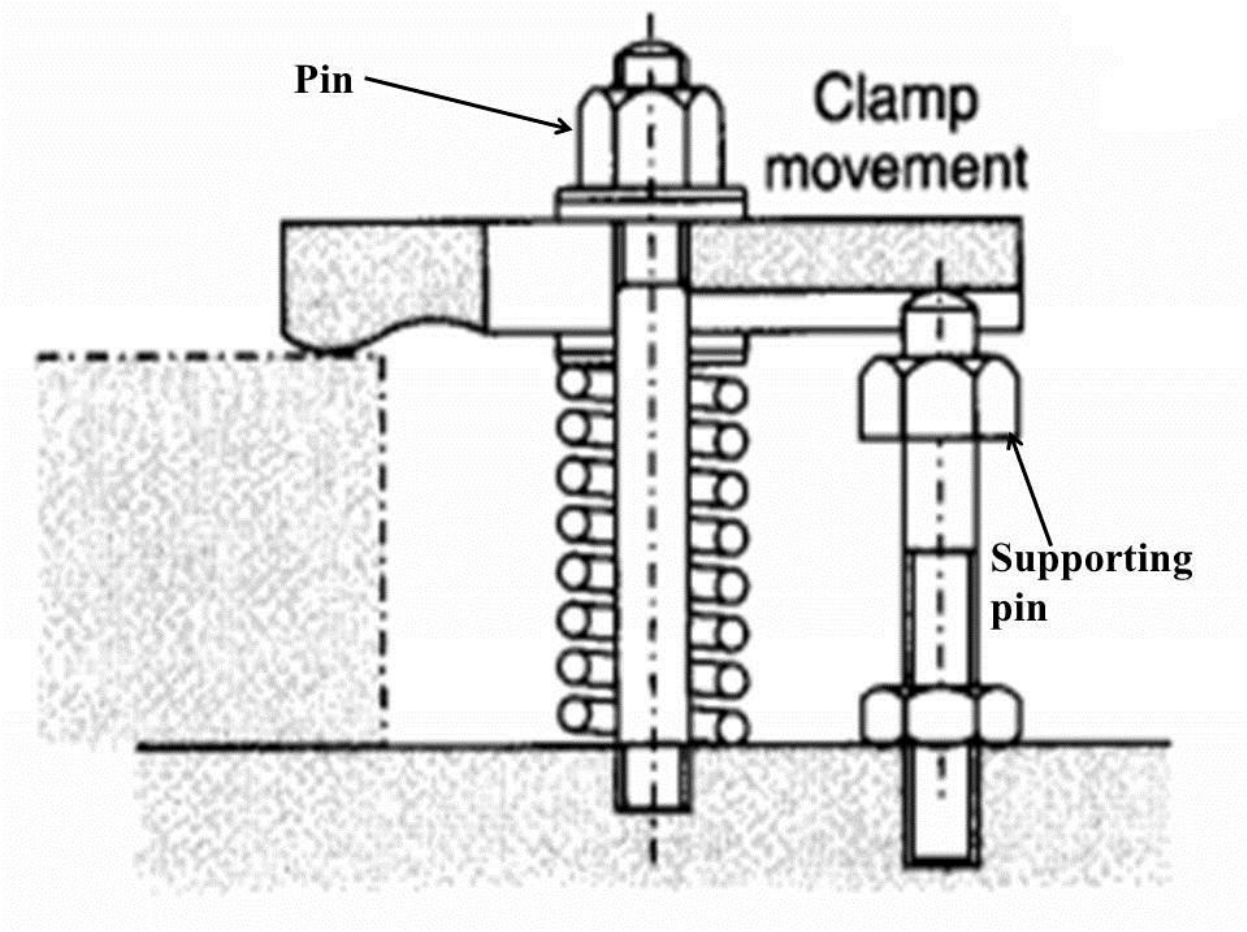

Fig.7 Strap clamp [5]

4.2.2. Screw clamp:

In screw clamp there are provisions for screw threads to clamp a job. It has knurled collar, head knob, tommy bar or spanner flats. These are provided for rotating and tightening the screw. Screw clamp is shown in Fig.8. Screw clamp exerts adequate force. It also resists tendency of loosening set up by vibration. But the disadvantage is that they are slow and may not be suitable for high production.

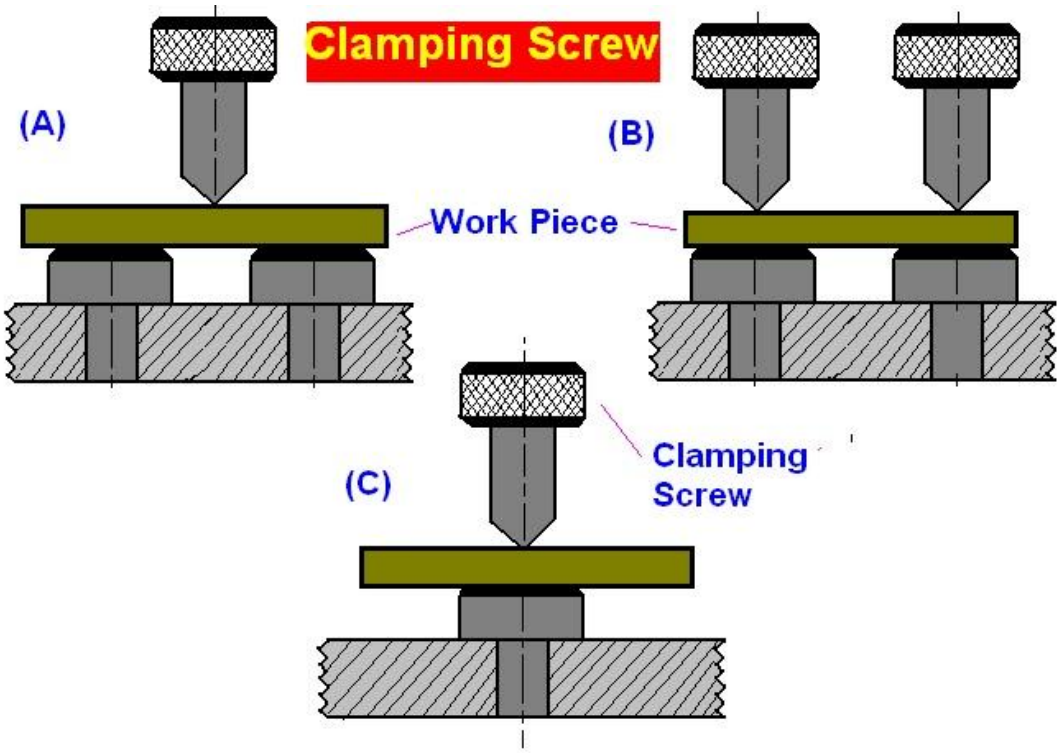

Fig.8 Screw clamp [6]

4.2.3. Toggle clamp:

Toggle is also quick action clamps. Toggle clamp is shown in Figs.9 - 10. These can be withdrawn by considerable distance for loading and unloading of the workpiece. These depend upon the movement of rigid links for their movement. These clamps are used extensively to hold the sheet metal parts in position while they are being welded or otherwise being fastened. They provide heavy clamping pressure.

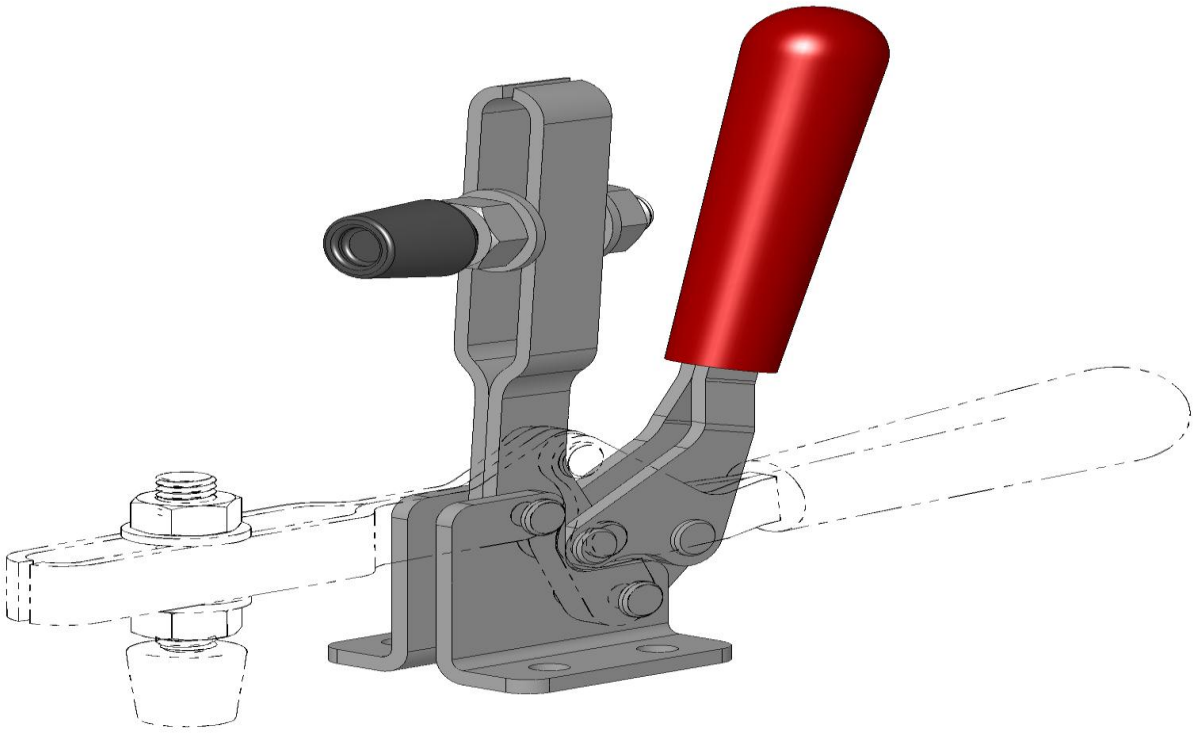

Fig.9 Toggle clamp [7]

Fig.10 3D view of the toggle clamp [8]

5. Methodology adopted:

The model was first prepared using CATIA software. The specification of heavy duty high torque drilling machine for which the model is being fabricated is listed in Table 3.

Table 3 Specifications of the drilling machine

Specifications	Value
Drill diameter	23mm
Power input	1150W
No load speed	280/640rpm
Weight	4.8kg

The drilling machine is called bench drilling machine which rests on a magnetic base to prevent its movement while drilling operation. The bench drilling machine is nothing but smaller than pillar drilling machine with all other things same to both the machines. The bench drilling machine is used to drill light-weight materials. One should never hold the material directly in hand while doing the drilling operation. Due to high torque the workpiece might rotate causing harm to the person holding the job. On-off switches are provided on the left side of the machine and the wheel to control the depth of drilling is provided on the right side of the machine.

The height of the table is set by adjusting the height adjuster lever. When drilling the table should be moved quite close to the drill bit so that the distance from the drill bit to the material is small.

Fig.11 shows the arrangement of the bench drilling machine along with its various parts.

Fig.11 High torque drilling machine

The material selected was of mild steel. During drilling operation a lot of force acts on the job as well as its holding device used in the holding of the job. The materials for fabrication should be selected such that this can be hardened to resist wear.

Materials generally used are:

- High speed Steel: Cutting tools like drills. Strength -2700 MPa.
- Die steels: Used for press tools, contain 1% carbon, 0.5 to 1% tungsten and fewer quantities of silicon and manganese.
- Carbon steels: Used for standard cutting tools. Strength-700 MPa.
- Collet steels: Spring steels containing 1% carbon, 0.5% manganese and less of silicon.
- Non shrinking tool steels: High carbon or high chromium Very little distortion during heat treatment. Used widely for fine, intricate press tools. Strength-750 MPa.
- High tensile steels: Used for fasteners like high tensile screws
- Mild steel: Used in most part of Jigs and Fixtures, Cheapest material, Contains less than 0.3% carbon.
- Cast Iron: Used for odd shapes to some machining and laborious fabrication. CI usage requires a pattern for casting. Contains more than 2% carbon. Have self-lubricating properties. Can withstand vibrations and suitable for base.
- Phosphor bronze: used for nuts as have high tensile strength. Used for nuts of the lead screw.

Considering the material given and its properties cast iron is used for the fabrication of the device. The dimensions of the material required for the production of the work holding device is shown in chapter 6.

Due to unavailability of cast iron of requisite thickness the material was first fabricated in teak wood. Different manufacturing machines were used in the process like pedal driven mortiser, bench drilling machine, hand saw and chisel. After the product is manufactured in wood it was first tested to be ok or not and later it can be used for the fabrication of the product. If it was not found suitable then it can be edited such that the same mistakes are not repeated in the main product.

The diagram of the mortiser which was mainly used in the machining of the product is shown in Fig.12.

Fig.12 Mortiser

This machine was used many times for creating holes or slots in the wood at required positions for holding different equipment like leaf and also accommodating the box within the main frame. When the pedal is applied the machine moves along Z axis vertically making slots or holes in the positions required. The wheels are provided to move the job from left to right along the X axis and also from towards the machine to away from the machine along the Y axis. Its specification is given in Table 4.

Table 4 Specification of mortiser

Parameter	Value
Weight	575lbs
Maximum depth	4”
Motor speed	3600rpm

6. CATIA 3D view with dimensions:

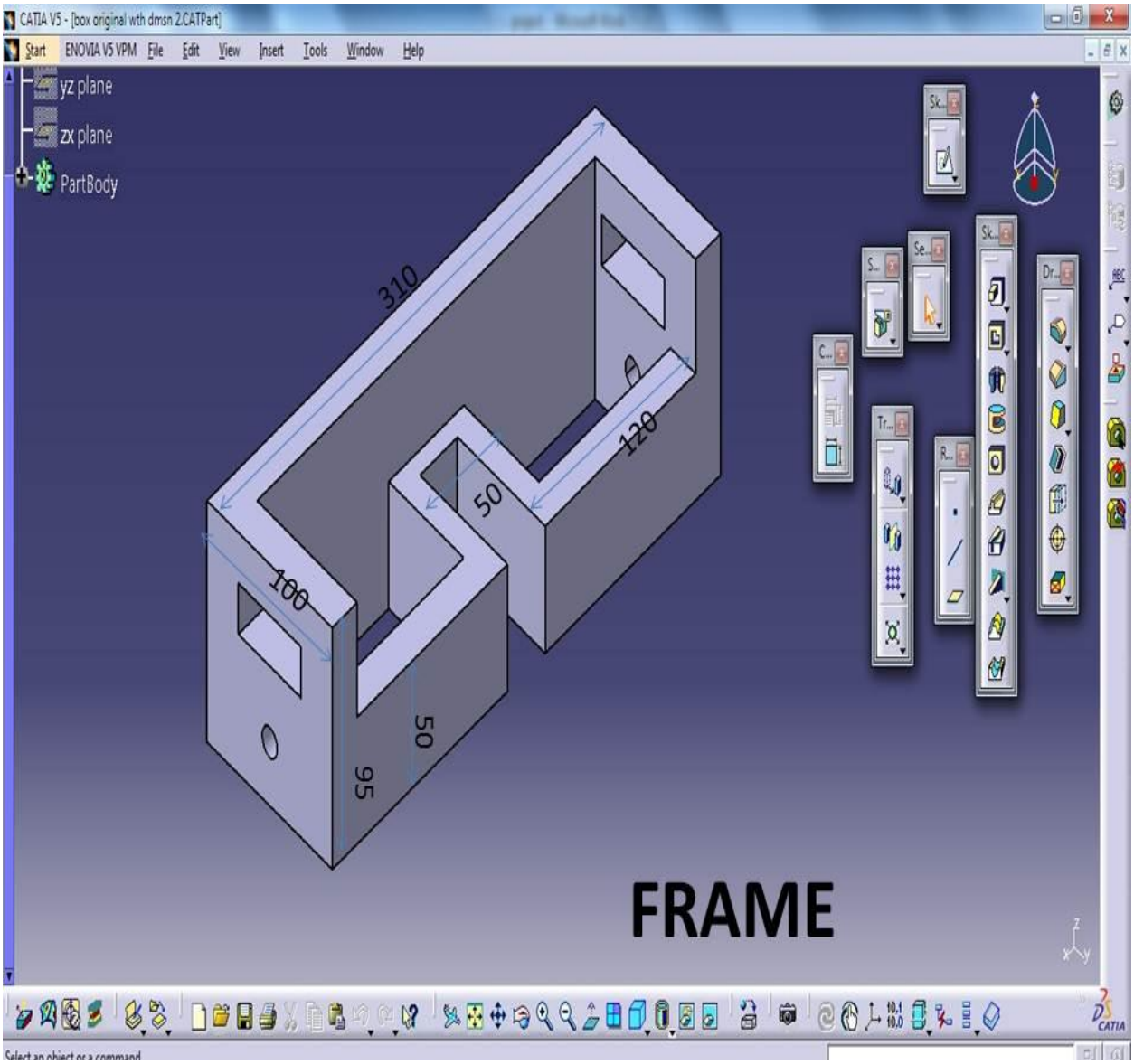

Fig.13 Frame with dimension

Fig.13 shows the frame of the product which holds the job to be machined at its right place. It has dimension of 310 mm X 100 mm X 95 mm. The two pockets shown above are to hold two boxes. There is also another rectangular slot which holds the box with its weight with the help of the leaf.

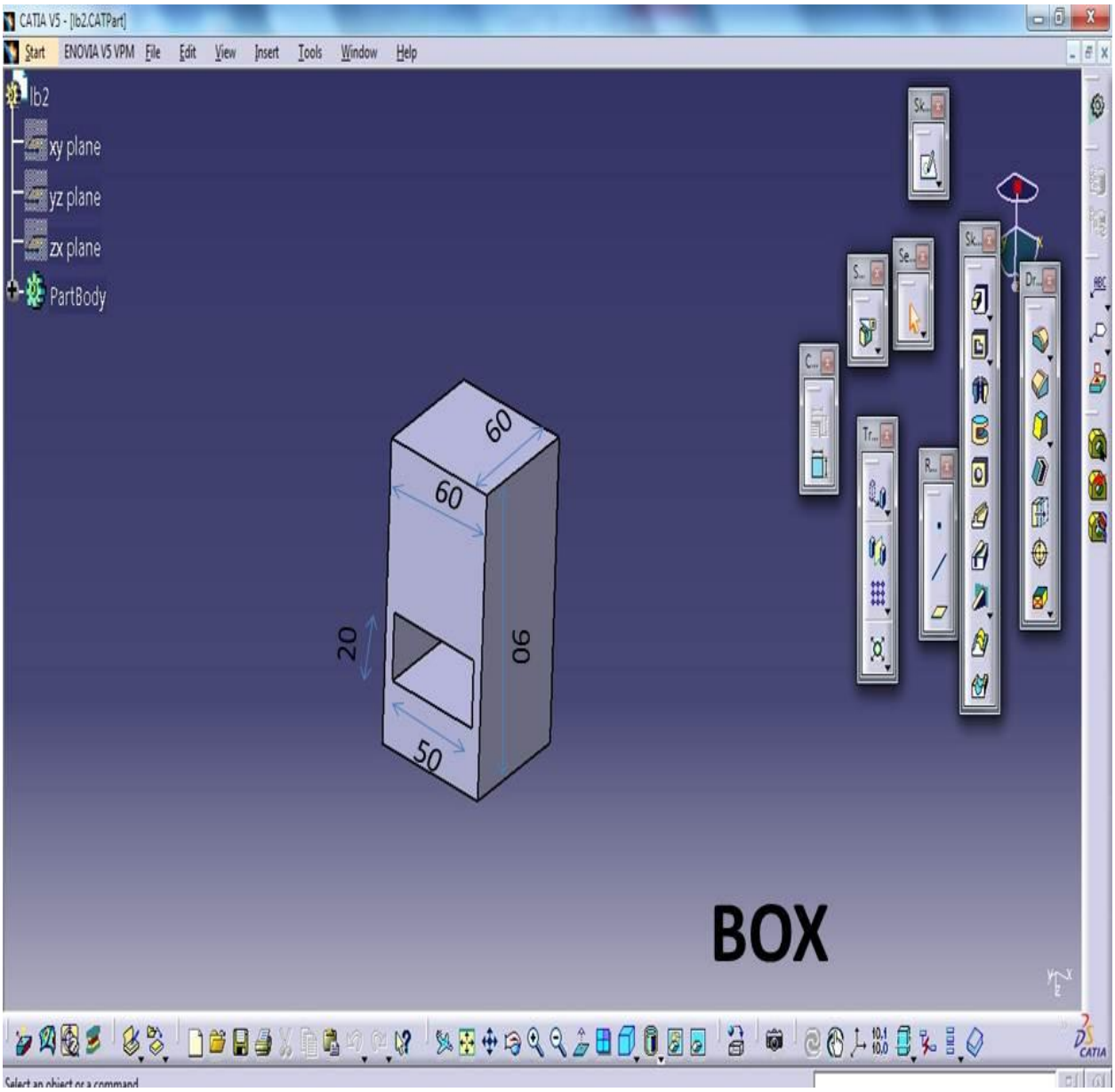

Fig.14 Box with dimension

Fig.14 represents the box. There are similar 2 boxes in the setup. The function of the box is to prevent the rotatory motion of the job during the drilling operation. It has dimension of 60 mm X 60 mm X 90 mm. It also has a slotted rectangular hole in between of dimension 50 mm X 20 mm. This hole holds the leaf in position and puts the weight of the leaf and the box over the job. As a result the job is restricted any linear motion.

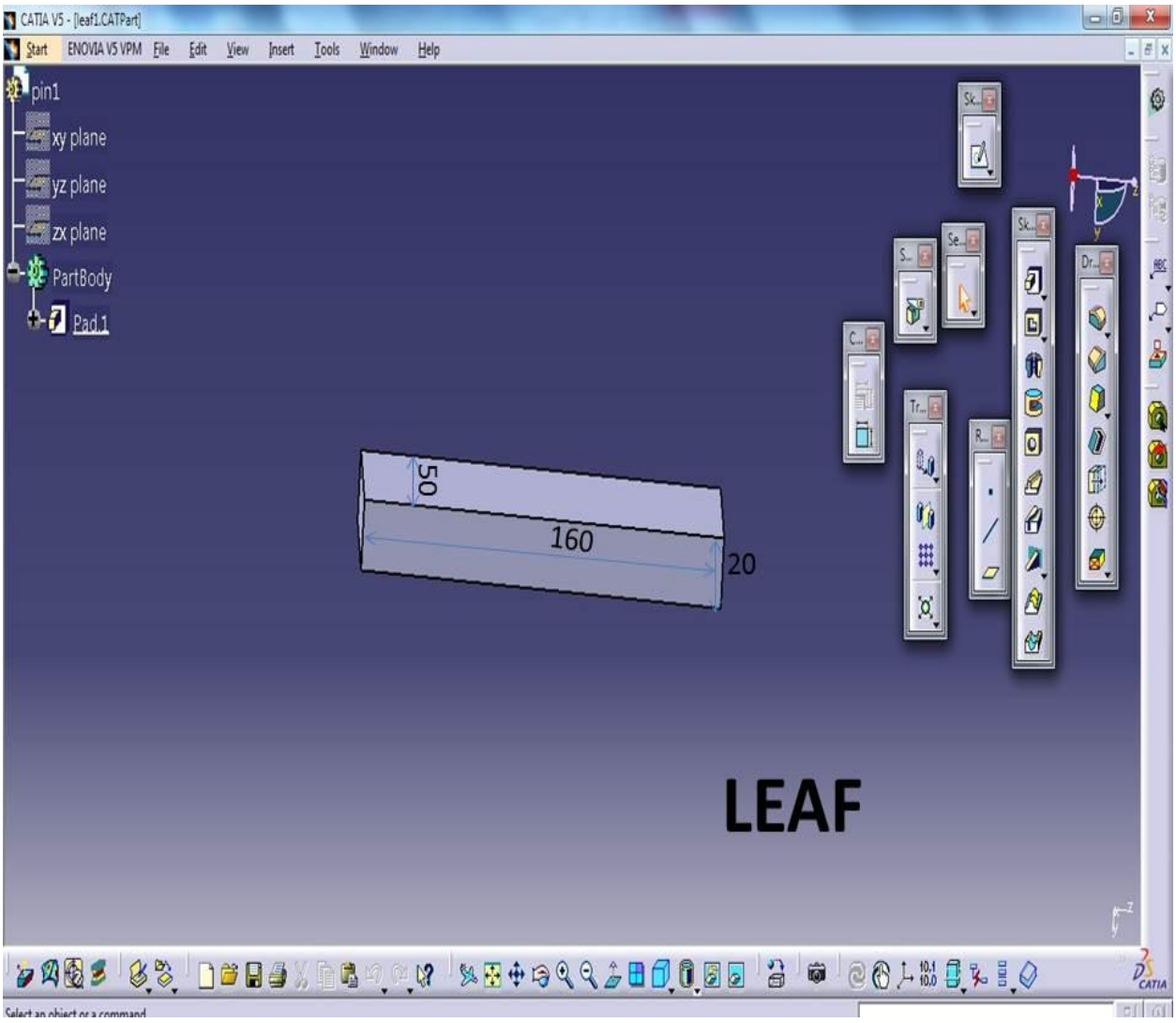

Fig.15 Leaf with dimensions

The leaf was constructed to hold the two boxes in position aligning with the hole of the frame. As a result the weight of the box and the weight of the leaf fall upon the job held between them. The job is also prevented from being rotating about Z axis. Thus the object can be machined without any failure. This is shown in Fig.15.

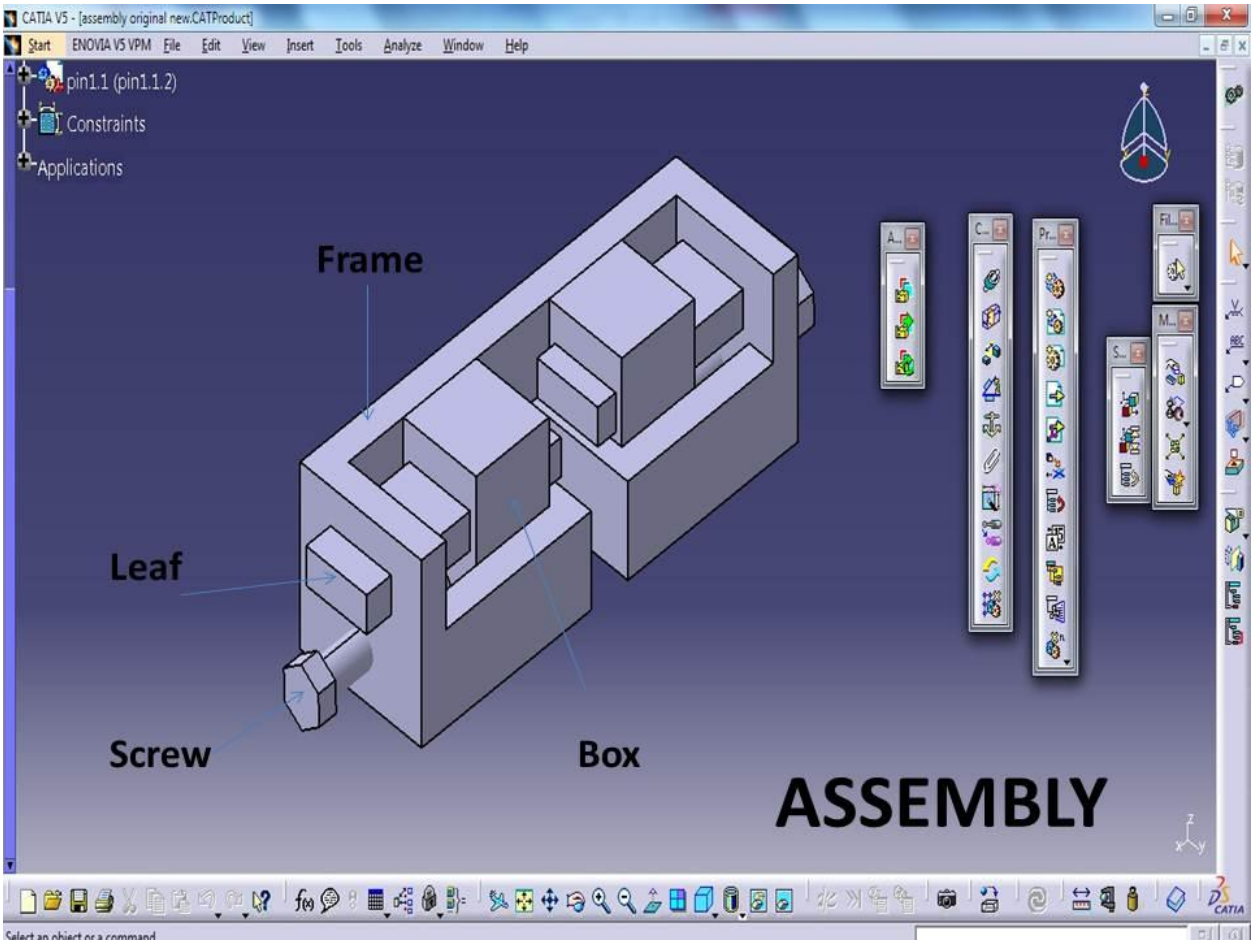

Fig.16 Assembly view of the final product

Here the frame, box, leaf and the two screws are assembled as shown in Fig.16. The job is held below the leaf at the edge of the box such that the job is prevented from being rotating. Also the linear motion of the job is restricted because of the weight of the leaf as well as the box. The box is tightened from the back with the help of two screws. These screw clamps ensure that the job is held tightly and box is prevented from being tilted.

7. Job constraints:

Table 5 Job constraints

Parameter	Constraint
Length	No constraints
Width	> 3 mm
Thickness	< 10 mm
Shape	Flat

Here the job of flat shape can be machined with constraints as shown in Table 5. It has no arrangement for machining a circular type of job. However development can be done on this product to make it suitable for machining a circular type of job and flat job with any thickness.

8. Results:

The object according to the given dimension and specification was fabricated in the workshop by wood as shown in Fig.17.

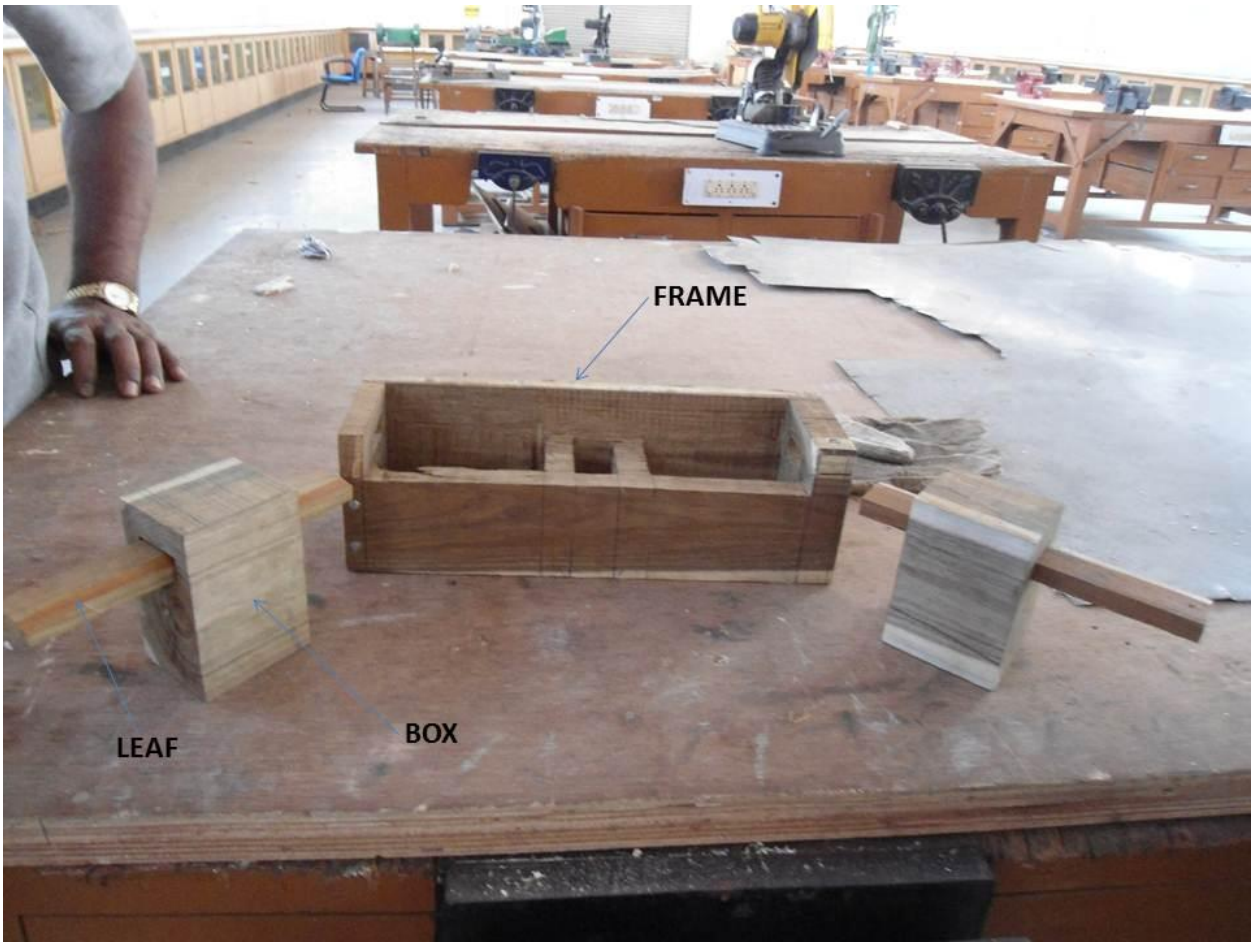

Fig.17 Fabricated job

The job was then assembled with the boxes kept at its position and leaves spread. The screws are attached at the back of the frame in order to hold the box and eventually the job rigidly at its fixed position. The assembled view of the fabricated product is shown in Fig.18.

Fig.18 The assembled view

9. Conclusion:

In this project, a complete model of work holding device of the high torque drilling machine was fabricated in the carpentry shop of the institute central workshop. Before fabrication a complete CAD model was prepared for optimum use of material and space. All the components were made locally. The device is controlled by tightening the screws provided on the rear side of the frame. The fixture can hold flat components and is operated manually.

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